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THE USE OF COMMERCIAL FERTILIZERS *

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Eight years ago the Illinois Farmers' Institute first requested the General Assembly to appropriate money to the State Agricultural Experiment Station for the purpose of investigating the soils of Illinois, in order that the landowners of this state might be furnished definite information which would enable them to adopt systems of farming that will maintain the fertility and productive capacity of Illinois soils; and it can now be said in confidence and in truth that sufficient positive knowledge has been secured to enable the majority of the landowners of this state to adopt permanent systems of agriculture, if they will; and, furthermore, this knowledge is so simple and so absolute and so freely furnished that any landowner who can read the English language and who has common sense can with a moderate amount of study understand what needs to be done.

More than 400 years ago Christopher Columbus discovered that the earth is round, but there are still to be found men living in the twentieth century who believe the earth is flat.

There are four great agricultural countries: China, India, Russia, and the United States. In these great countries the people must be supported by their own agriculture. I have a letter written from China two years ago this month in which the following statement was made concerning the famine district in which the writer was located. He said:

*An address read before the Illinois State Farmers' Institute at Rockford, February 25, 1909.

"At the present time the only practical thing to do is to let 400,000 people starve, and try to get enough seed grain for the remainder to plant their spring crops."

At that time the people of Illinois took up collections in their churches for the relief of the Chinese famine. It is not uncommon for a million people to die of starvation during a famine in China.

I have another letter from China written by a graduate of the University of Illinois who is now in that country, in which he describes how thousands of Chinese women are called dung women, because with dung baskets on their arms they spend their days and their lives gathering from the streets and gutters the excrements of animals and of men, in order that they may exchange these fertilizing materials with the gardeners for food.

This is not only the present practice, but a long continued custom. About one hundred years ago an English resident of China wrote:

"Human urine is, if possible, more husbanded by the Chinese than night soil for manure... ... The business of collecting urine and night soil employs an immense number of persons, who deposit tubs in every house in the cities for the reception of the urine of the inmates, which vessels are removed daily with as much care as our farmers remove their honey from the hives. The night soil is collected in the same way, as well as on the roads and by-places, persons being always on the alert with baskets and rakes to avail of the least particle that appears."

And yet there are people in Illinois who believe that our soils are inexhaustible.

I have a near relative, who was born and raised on a neighboring farm in Minnesota, who has devoted nine years of his life to India. From him, and from many other reliable sources, I learn of the common want and misery and famine and starvation in that great agricultural country, where as an average more people are hungry than live in the United States.

Investigations made by special agents of the Bureau of Statistics of the United States Department of Agriculture report that the average yield of wheat for the Russian Empire for the 20 years, 1883 to 1902, was 8¼ bushels per acre, and as a rule the land lies fallow every third year. The following comment is recorded on page 27 of Bulletin 42 of the Bureau of Statistics:

"It may be claimed that this extremely low average yield in European Russia is caused by the total failure of crops in famine years, and that these should have been omitted in calculating the average for a series of years. But the extreme variability of the average yield is no less a characteristic feature

> of Russian agriculture than its very low yield; and the famine years have been so frequent as to become a permanent feature of Russian agriculture, each one of the five-year periods including at least one famine year, and some even two."

In famine years the average yield of wheat for the Russian Empire is 6¼ bushels per acre. There is no record of an average yield of less than 5½ bushels.

There are thousands of acres of level or gently rolling lands within a hundred miles of the city of Washington that were once worth $50 to $75 an acre that are now abandoned for agricultural purposes, that sell for less than $10 an acre, or, in some cases, that are absolutely disowned; and yet there are teachers who tell us that practically all soils contain sufficient plant food for good crop yields, that this supply will be indefinitely maintained, and that it is never necessary at any time to introduce fertilizing material into any soil for the purpose of increasing the amount of plant food in that soil.

I have never found a large audience of Illinois landowners in which there were not a dozen or more who could testify from their own knowledge that the average farm lands of New England, New York, Virginia, and other Eastern States have markedly decreased in productive power and in value, in many cases to such an extent that the farms can now be bought for less than the buildings cost; and yet there are people in Illinois who seem to think that this condition can never come upon Illinois lands.

Because the few acres of land that are still kept in cultivation in New England produce larger crops per acre than some of the great areas of the Central West, some tell us that if we work our Illinois lands hard enough we can always produce as large or larger crops without returning any plant food to the soil. The facts are that from $2 to $20 an acre are frequently expended for plant food on the soils of the Eastern States where crops are still grown. Immense quantities of stable manure, made in large part from the grain and hay shipped from the West, are used to build up and maintain the small proportion of farm lands still under cultivation in the densely populated sections of the East.

It is true that the yield of corn in Rhode Island and Connecticut is greater than the average yield in Illinois; but *listen:* The total corn acreage of Rhode Island is less than half of one township; the total corn acreage of Rhode Island and Connecticut combined is less than one-tenth of one county in Illinois; and the total corn acreage of Maine, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, New York, Pennsylvania,

New Jersey, Delaware, and Maryland, all combined, is less than the corn acreage of Georgia, and less than one-half the corn acreage of Illinois.

Messrs. Whitney and Cameron of the Bureau of Soils, of the United States Department of Agriculture teach that large crops can be removed year after year and that no plant food need ever be returned to the soil. Their earlier publications, (as Bulletin 22 of the Bureau of Soils) include nitrogen as well as phosphorus and potassium as being contained in, or naturally furnished to, all the soils in sufficient abundance to meet the needs of present and future crops indefinitely, but in their later publications, altho they have not retracted their former statements, they sometimes say *mineral plant food* instead of *all plant food*. They teach that crop rotation alone will maintain the fertility of the soil, and cite as proof a Rothamsted rotation in which no legume crops were grown (turnips, barley, bare fallow, and wheat).

They teach that, because the average yields of wheat and of some other crops are greater in England and in other small European countries, than the yields of the same crops in the United States, therefore, land becomes more and more productive the longer it is cropped and cultivated.

Do not forget that Texas is larger than the largest European country outside of Russia. It is true that the average yield of wheat in England is reported as 32 bushels per acre, but it is also true that five of our states, combined, including Illinois, produce five times as much wheat as England. England produces only about 50 million bushels of wheat and imports about 200 million bushels of wheat, 100 million bushels of corn, and almost a billion pounds of oil cake, besides large supplies of other foodstuffs and provisions. All of these furnish large quantities of fertilizing materials; and, in addition to the manure saved from these foodstuffs, the farmers of England, as well as those of other small European countries, use phosphates and other commercial plant food materials to the extent of several hundred thousand tons annually.

Belgium, a country one-fifth the size of Illinois, produces 12 million bushels of wheat, or about one-third as much as Illinois; but Belgium imports 60 million bushels of wheat, 20 million bushels of corn, and half a billion pounds of oil cake.

Germany, which is four-fifths as large as Texas, produces 125 million bushels of wheat, but Germany consumes 200 million bushels of wheat; and, besides, Germany imports 40 million bushels of corn, more than a billion pounds of oil cake, and other food-

stuffs. What does Germany export? Her principal export is 2 billion pounds of sugar, which contains absolutely no plant food of value.

Denmark produces 4 million bushels of wheat, and, in addition, imports 5 million bushels of wheat, 15 million of corn, and 800 million pounds of oil cake. And what does Denmark export? Principally, 175 million pounds of butter, which contains practically no plant food and which sells for twice as much as the imported wheat, corn, and oil cake cost.

The one reason that stands far above all the other reasons why England produces larger yields of wheat than the United States is, because the English farmer uses plant food, liberally and persistently, and the same is true of other small European countries.

In his American Lectures on the Results of Investigations on the Rothamsted Soils, Doctor Bernard Dyer, of England, in discussing the experiments on Broadbalk field where 15.7 tons per acre of farm manure have been applied every year for more than fifty years, made the following statement:

> "It is to be borne in mind, however, that the quantity of dung used in these continuous wheat-growing experiments is, on the yearly average, far less than would be used in practical agriculture on any of the rotation systems". (See page 50, Bulletin, 106 of the Office of Experiment Stations, United States Department of Agriculture.)

Those countries that feed practically all they raise and buy in addition large quantities of fertilizers, and other food stuffs from which to produce still larger amounts of manure, can thus make their soils richer than they ever were. Likewise the market gardeners who haul manure from town, and dairymen who buy much bran, oil meal, and other foodstuffs, and stock feeders who feed all they raise and buy much corn from their neighbors,—all these can, and usually do, maintain or increase the fertility of their own farms; but meanwhile the great agricultural areas of the United States are being steadily depleted.

Furthermore, we must not be deceived by the general statistics that are sometimes quoted to show an increase in the average crop yields of some states. Thus, in this new rich state of Illinois, the average yield of corn has increased in the past ten years; but this does not prove that Illinois soils are growing richer. During the past ten years the annual corn area of Illinois has increased from 7 million to 9 million acres, and the added 2 million acres are the richest black soil of the state, including old blue grass pastures, low-lying prairies or swamp lands reclaimed by

dredge ditching and tile drainage, and river bottoms protected by dikes or ditches. Meanwhile some portions of the older lands, represented by the 7 million acres of corn of ten years ago are now producing smaller crops. The improvement in seed and in methods of cultivation and crop rotation have done much to deplete the soil, but to maintain, temporarily, fairly good yields, even on our older corn belt lands.

No man of sense prefers to criticize or oppose another; and I trust you will believe me when I say that from personal choice I would never mention the teaching of Whitney and Cameron of the United States Bureau of Soils; but there is another consideration: What is the duty of the University of Illinois to the Illinois landowner and to the future welfare of this commonwealth?

The farmers of this state through their farmers' institute have asked their Agricultural Experiment Station to secure information concerning systems of farming that will permanently maintain the fertility of Illinois soils; and 250,000 landowners have a right to ask the same questions that large numbers have asked and are asking regarding the teachings of the United States Bureau of Soils, which are persistently disseminated over this state by bulletins, circulars, and in newspaper articles and press dispatches. Thus, recently, from different sections of the state have come requests for an opinion upon an article published broadcast in the daily press, dated Washington, December 10, 1908, and carrying these headlines:

SOIL WON'T WEAR OUT

INSTEAD, YIELD WILL INCREASE TEN FOLD IN TIME

"Prof. Milton Whitney Declares Investigation Shows Productive Power Increasing and Sufficient to Feed Nation for Centuries."

In this article, Professor Whitney is quoted as saying:

> "It is apparent the land in farms at present can be expected to produce in time something like ten or twelve times the amount of crops that are now produced on these farms.
>
> "So far as the present outlook is concerned, the nation possesses ample resources in its soils for any conceivable increase in population for several centuries.
>
> "The Bureau of Soils find that the decline in yield is generally due to the accumulation of organic products in the soil which are not eliminated through proper cultural methods as fast as they have accumulated, and that the failures that are reported are, therefore, due to improper methods of cultivation and of crop rotation."

In *The Country Gentleman* of February 18, 1909, is reported an address delivered by Professor Whitney at Columbia, Missouri, on January 9, 1909, in which he is credited with the following statements:

> "It is not so necessary to go very far in investigation to reach the conclusion that we have in our soils a great natural asset, a dish out of which we can eat and eat and eat, today, tomorrow, and forever.
>
> "That you may not think that it is a dream, I may say that there are unknown forces which have been at work for the accomplishment of this end. If we handle our soils with skill and intelligence, we may have the dream of the philosophers realized, we may have a thing that can be used and used over and over again. There is nothing more certain than that we have in our soil a permanent and inexhaustible asset."

Surely we would all rejoice if these statements were true; but are they true? They are not true for China, not true for India, not true for Russia, and they are not true for the United States. In no old country are large crops produced except where plant food is applied either artificially or naturally; and Illinois cannot afford to wait 25 or 50 years before adopting definite systems of permanent soil improvement; for, if we once allow our lands to become depleted and impoverished as are those of old Virginia, for example, then it will be too late to make any investments in soil improvement. Poverty is helpless, and continued poverty brings ignorance. Only the prosperous can afford education and trained intelligence.

Someone will say that here is a case where scientists disagree, but let me tell you that scientists never disagree. Theorists may disagree, but not scientists. Science means knowledge, and men are scientists only to the extent of their absolute knowledge. The true scientist will never ask that you accept his opinion; he only asks that you accept his facts.

I have some facts I will ask you to accept and consider:

Thus, I have the exact average yields of corn and oats for the last six years from 90 farms in the heart of the Illinois corn belt,—yields from measured land, and from the scales. In 1908 these 90 farms included 7,455 acres of corn, 5,417 acres of oats and 1,959 acres of meadow, pasture, and lots. In the main, the corn and oats have been rotated, and for several years some clover has been grown on every farm.

The average yields of these 90 farms for the last six years are 39.3 bushels of corn and 33.4 bushels of oats; and the average yields for the last three years are 36.6 bushels of corn, and 28.2 bushels of oats. The selection and care of seed, the preparation

of the land, and the planting and care of the crop will average better on these 90 farms than on the average corn belt farm. *These are facts, not theories.*

On one of these same farms the University of Illinois conducts an experiment field. The application of two elements of plant food, nitrogen and phosphorus, in dried blood and steamed bone meal, together with a small amount of lime, increased the yield of corn in 1902 from 57.3 bushels to 57.3 bushels, which was no increase at all; increased the yield of corn in 1903 from 50.4 bushels to 69.1 bushels; increased the yield of oats in 1904 from 74.4 bushels to 88.4 bushels; increased the yield of wheat in 1905 from 29.5 bushels to 45.2 bushels; increased the yield of corn in 1906 from 36.7 bushels to 68.5 bushels; increased the yield of corn in 1907 from 33.9 bushels to 72.3 bushels; and increased the yield of oats in 1908 from 25.9 bushels to 45.6 bushels per acre.

Here we have had exactly the same rotation and the same cultivation on both plots for seven years, but as an average of the last two corn crops the yield was 35.3 bushels on the untreated land and 70.4 bushels per acre where plant food has been applied. These are facts, not theories; and they are in harmony with other facts secured during the past seven years from more than twenty soil experiment fields conducted by the University of Illinois in different parts of this state.

I ask you to accept two other Illinois facts: The plowed soil of an acre of the commonest prairie land of the Illinois corn belt does not contain enough nitrogen for 35 such crops of corn as we harvested in 1908 from our best treated land, and not enough total phosphorus in the plowed soil, 7 inches deep, for 55 such crops. *These also are facts, and not theories.*

In 1848, Sir John Lawes and Sir Henry Gilbert began at Rothamsted, England, two 4-year rotations. One was turnips, barley, fallow, and wheat; and the other was turnips, barley, clover, and wheat. Whenever the clover failed, which has been frequent, beans were substituted, in order that a legume crop should be grown every fourth year.

The average of the last 20 years, ending 1907, represents the average yields 50 years from the beginning of this rotation.

In the fallow system, as an average of the last 20 years, the use of mineral plant food has increased the yield of turnips from 1½ tons per acre to more than 10 tons per acre; has increased the yield of barley from 15.9 bushels to 15.9 bushels (or no increase at all); and has increased the yield of wheat from 23.5 bushels to 28 bushels per acre. (The fallow adds no nitrogen but it liberates

some nitrogen from the soil for the following wheat and turnip crops).

In the legume system, as an average of the last 20 years, the use of mineral plant food has increased the yield of turnips from less than ½ ton to more than 12 tons; increased the yield of barley from 13.7 bushels to 22.2 bushels; increased the yield of clover (when grown) from less than ½ ton to almost 2 tons; increased the yield of beans (when grown) from 16 bushels to 28.3 bushels; and increased the yield of wheat from 24 3 bushels to 38.4 bushels per acre.

In the legume system the minerals applied have more than doubled the value of the crops produced, have paid their cost, and made a net profit of 140 per cent on the investment, in direct comparison with the unfertilized land.

If we compare the average yields of turnips, barley, clover, and wheat of the last 20 years, from 1888 to 1907, with the yields of turnips in 1848, barley in 1849, clover in 1850, and wheat in 1851 we find that on the unfertilized land in this rotation of crops in fifty years the yield of turnips has decreased from 10 tons to ½ ton, the yield of barley has decreased from 46 bushels to 14 bushels, the yield of clover has decreased from 2.8 tons per acre to less than ½ ton, while the yield of wheat has decreased only from 30 bushels to 24 bushels. As a general average the late yields are only one-third as large as they were 50 years before on the same land. Wheat grown once in four years has been the only crop worth raising on the unfertilized land during the last 20 years, and even the wheat crop has distinctly decreased in yield; altho where mineral plant food was applied, the yield has increased from 30 bushels, in 1851, to 38 bushels as an average of the last 20 years. In the fallow rotation on the unfertilized land the yield of wheat averaged 34.5 bushels during the first 20 years (1848 to 1867) and 23.5 bushels during the last 20 years (1888 to 1907.)

These are the rotation plots, on Agdell Field at Rothamsted, whose wheat yields are cited by Professor Whitney to prove that crop rotation will maintain the fertility of the soil. But what do the people of Rothamsted say? Director Hall says:

"I cannot agree with Professor Whitney's reading of the results on the Agdell field in the least. The figures he quoted for wheat are hardly justifiable as approximations and are in spirit contrary to the general tenor of the particular experiment.....In my opinion the results on the Agdell rotation field.....are directly contrary to Professor Whitney's idea that rotation can do the work of fertilizers."

On another Rothamsted field the phosphorus actually removed in 55 crops from well fertilized land is two-thirds as much

as the total phosphorus now contained in the plowed soil of adjoining untreated land. *I ask you to accept that fact.*

At Wooster, Ohio, the Agricultural Experiment Station has conducted a 5-year rotation of corn, oats, wheat, clover, and timothy, for fifteen years, on five different series of plots so that every crop is represented every year. Surely a five-year rotation, including three different grain crops, followed by two years in grass, ought to be sufficient to meet Professor Whitney's specification for "arranging a system of rotation and growing each year a crop that is not injured by the excreta of the preceding crop" so that "when the time comes around for the first crop to be planted again the soil has had ample time to dispose of the sewage resulting from the growth of the plant two or three years before." But is crop rotation all that Ohio soils need? As an average of fifteen years the increase produced by commercial plant food has been 18 bushels of corn, 18 bushels of oats, 16 bushels of wheat, 1300 pounds of clover, and 1000 pounds of timothy hay, per acre, per annum. As a general average of all crops grown during the fifteen years, the yield has been more than 50 percent above the same crops on the unfertilized land. *These are plain American facts*, from a state where much of the land is worth only half as much as it was 40 years ago.

In 1882, the Pennsylvania Agricultural Experiment Station began a four-year crop rotation, including corn, oats, wheat, and mixed clover and timothy. If we disregard the first three years, which were required to get the rotation and treatment fully under way, we still have the record of 24 years, 1885 to 1908.

There are five plots in each of four different fields that have received no applications of plant food from the beginning. Thus, every year the crops are carefully harvested and weighed from 20 measured plots of ground that receive no treatment except the rotation of crops. The difference between the average of the first 12 years and the average of the second 12 years should represent the actual change in productive power during a period of 12 years. These averages show that the yield of corn has decreased from 41.7 bushels to 27.7 bushels; that the yield of oats has decreased from 36.7 bushels to 25.0 bushels; that the yield of wheat has decreased only from 13.3 bushels to 12.8 bushels; and that the yield of hay has decreased from 3070 pounds to 2180 pounds.

As a general average of these four crops the annual value of produce from one acre has decreased from $11.05 to $8.18. Here we have information which is almost if not quite equal in value to that from the Agdell rotation field at Rothamsted. While the

Rothamsted experiments cover a period of 60 years, each crop was grown but once in four years, so that during the 60 years there have been only 15 crops of wheat, 15 crops of turnips, 15 crops of barley, and 15 crops of legumes; whereas in the Pennsylvania experiments, there have been four different series of plots, so that in 24 years there have been 24 crops of corn, 24 crops of oats, 24 crops of wheat, and 24 crops of hay.

Under this four-year rotation the value of the crops produced has decreased 26 percent in 12 years. What influence will impress that fact upon the minds of Illinois landowners? A loss amounting to more than one-fourth of the productive power of the land in a rotation with clover seeded every fourth year! This one fact is the mathematical result of 480 other facts obtained from 20 different pieces of measured land during a period of 24 years.

As an average of these 24 years, the addition of mineral plant food produced increases in crop yields above the unfertilized land as follows:

Corn increased 45 percent.	Wheat increased 42 percent.
Oats increased 32 percent.	Hay increased 77 percent.

As a general average of the four crops for the twenty-four years, the produce where mineral plant food is applied, was 49 percent above the yields of the unfertilized land, altho the same rotation of crops was practiced in both cases.

Gentlemen, of the Illinois State Farmers' Institute, I pause to emphasize my obligation and your obligation, to Lawes and Gilbert, two of the greatest benefactors the world has ever known, who labored together for 57 years at Rothamsted, gathering agricultural facts,—and to emphasize our obligation to A. D. Hall, the present Director of the Rothamsted Experiment Station, to Charles E. Thorne, the Director of the Ohio Experiment Station, and to Thomas F. Hunt. a Northern Illinois boy, a University of Illinois man, the present Directr of the Pennsylvania Experiment Station,—to emphasize our obligation to these men, because they have made it possible for me to furnish you with 1908 facts. (See also the photographic reproduction on the last page.)

There is one other fact I ask you to accept: Carloads of cattle and hogs are not made out of nothing; and, consequently, no farmer who hauls crops off from his fields can haul back sufficient fertility in the manure made from those crops to replace all that he hauls off the land.

Live stock farming has never maintained the soils of any country unless plant food was purchased in fertilizers or in foodstuffs, in addition to what was raised on the farm.

Shall we use commercial fertilizers? The answer to this question depends upon what is meant by commercial fertilizers.

What are commercial fertilizers? How much do they cost? How long will they last? Will they injure the soil?

If one begins using commercial fertilizers, must be keep on using them, or will his land become poorer than ever if he stops using them? What kind should one buy? How can he tell what his land needs? Can one be sure that he gets what he pays for? Are the fertilizer manufacturers reliable?

Can we permanently maintain the fertility of the soil with commercial fertilizers? Do most farmers who have come from the Eastern states advise us never to begin using commercial fertilizers?

What is acid phosphate? Is it just as good as bone meal?

What is raw rock phosphate? Is it available? Is it the same thing as limestone? Wouldn't any kind of ground rock do just as well? Will raw rock phosphate do any good the first year? Will it take the place of manure and clover?

Don't the farmers who get up at four o'clock in the morning and work till nine o'clock at night know all about these things? Haven't they alway kept up the fertility of the soil? Aren't the farms of New England and Old Virginia and Georgia worth more today than those of Illinois? Aren't old lands always richer than new lands? I shall try to answer a few of these questions, most of which are questions that are very commonly asked by Illinois farmers.

First, What are commercial fertilizers?

In answer to this I may say that in Georgia, where more commercial fertilizers are used than in any other state; in Georgia, where 4½ million acres of corn are grown; in Georgia, where the average yield of corn for the past ten years is 11 bushels per acre; in Georgia commercial fertilizers are as follows:

American Eagle	Magic Cotton Grower
Electric Crop Grower	Monarch Vegetable Grower
Farmers' Standard	Nature's Plant Food
Farmers' Favorite	Planters' Favorite
First Call	Perfection Special
Gilt Edge	Potato Compound
Gem Cotton Grower	Standard Golden Harvest
Golden Fleece	Southern Hustler
Golden Tobacco Producer	Tip Top
Georgia Formula	Union Crop Grower
Lyon Favorite	Uneedit Fertilizer

I have read to you the names of only 22 different brands of

fertilizers; but you will be interested to know that in Georgia there are just 1822 brands of commercial fertilizers that are sold to the farmers in that state; and, of these 1822 commercial fertilizers, not one contains more than three valuble elements of plant food, nitrogen, phosphorus, and potassium; and, furthermore, nitrogen is contained in the air in absolutely inexhaustible amount, and potassium is contained in all normal soils in essentially inexhaustible amounts.

As a general average of the most common commercial fertilizers sold in Georgia and in other parts of the United States, one ton contains about 35 pounds of nitrogen, 80 pounds of phosphorus, and 35 pounds of potassium; and the average retail price for such fertilizers in Illinois is $23 per ton; while the same amount of phosphorus can be purchased in raw rock phosphate for about $2.30.

To supply as much nitrogen as was required to produce the best yield of corn grown by the Illinois Experiment Station in 1908 would require 4½ tons per acre of this $23 fertilizer. To supply the potassium would require more than two tons; but sufficient phosphorus for the same crop could be bought in this average commercial fertilizer for about $8.00 an acre, or in raw rock phosphate for 80 cents an acre.

These figures give a fair idea of the cost of common commercial fertilizers for use in systems of farming in which the fertility of the soil is to be maintained. These figures tell us that the entire crop of corn is not worth what the fertilizer would cost if we supplied either sufficient nitrogen or sufficient potassium to meet the actual requirements of the crop.

Will the use of commercial fertilizers injure the soil?

There are two ways, and possibly three, in which the use of the common commercial fertilizers injures the soil. First, they actually contain practically the full measure of the acidity represented by the sulfuric acid used in their manufacture. They do not contain sulfuric acid as such, nor any other free acid; but they do contain acid salts, which require just as much lime for their correction or neutralization as would the sulfuric acid itself. On the whole, however, this tendency to produce, or increase, acidity in the soil is a minor matter, because it can be corrected from time to time by the addition of ground limestone at small expense.

The second way in which the use of commercial fertilizers injures the soil is of much greater importance, altho it is indirect. It is due to the fact that they are too expensive to permit their use in sufficient quantity to supply as much plant food as

the crops remove; and the result is that where they are used they serve in part as soil stimulants.

To illustrate this: Suppose one applies 200 pounds to the acre of the average commercial fertilizer, at a cost of $2.30, and then harvest a crop of 60 bushels of corn. He will remove in the corn crop about twice as much phosphorus, ten times as much potassium, and twenty-five times as much nitrogen, as he applied in the fertilizer. The facts are that he has not only removed more plant food than was furnished in the fertilizer, but he has taken more from the soil itself than he could have taken without the fertilizer, because the quick acting fertilizer has stimulated the early growth of the plants and enlarged the root systems and thus enabled the crop to draw more heavily upon the soil. Besides this, the fertilizer contains manufactured landplaster, which is one of the most powerful soil stimulants. Suppose the farmer grows oats the next year without fertilizing, applies another 200 pounds per acre for the following wheat crop, and then with no further additions grows two crops of timothy and clover hay. He can thus wear his soil out more rapidly than he could without the stimulating action of the fertilizer. This would not be the case if he would apply more plant food than his crops remove.

There is a third way in which commercial fertilizers may possibly injure the soil. The value of steamed bone meal and of raw rock phosphate is due to the tricalcium phosphate which they contain. When these materials are treated with sulfuric acid, the insoluble, neutral tricalcium phosphate is converted into soluble, acid monocalcium phosphate; and, at the same time the sulfuric acid is converted into calcium sulfate, which is essentially the same compound as plaster of Paris, a well known material with strong cementing properties. It is a fact, that with the long continued use of acid phosphate, alone or in mixed fertilizers, the soil usually becomes harder and more compact. That is to say, it develops a bad physical condition. In large part, this is probably due to the destruction of humus or organic matter, but to some extent it is very possibly due to this manfacutured cementing material.

In comparison with this, you who heard Director Hall of the famous Rothamsted Experiment Station, the oldest in the world, when he lectured at the soil fertility meetings that were held at the University of Illinois last July, will remember that he gave positive proof of the injurious effect upon the physical condition of the soil resulting from the continued use of sodium nitrate; and he also reported, in harmony with the experience of others,

that the use of ammonium salts tends to develop soil acidity in actual field use.

How can one tell what his land needs? There are two ways in which this can be done. One way is to employ a commercial chemist to analyze the different kinds of soil from your fields, and then conduct exact experiments on your own farm for a number of years. The other way is to study the bulletins and reports from the soil survey and from the soil experiment fields, published by your Experiment Station, which any one can obtain for a one cent postal card, and which can be understood and utilized by any man or woman of "gumption".

Are the fertilizer manufacturers reliable? Some of them are and some are not; and the same may be said of men in general, including both the farmers of Illinois and the soil investigators of the United States. The advice to "prove all things and hold fast that which is good" is needed today as much as ever.

There are three elements of plant food that have a commercial value; but this does not mean that all three of these elements will have an agricultural value on your land. Some soils are deficient in one element, and some in another; and frequently a soil is found that is deficient in two elements; but no soil is found in Illinois that is deficient in all of these three elements.

There are about 80 primary elements, and they constitute the basis of all matter. About 20 elements are common but only 9 elements can be considered relatively abundant; water consists of oxygen and hydrogen; the air consists largely of oxygen and nitrogen; and the earth consists largely of oxygen, silicon, aluminum, iron, calcium, magnesium, potassium, and sodium; while the only element of plant food that is relatively limited is phosphorus.

Nitrogen is one of the three valuable elements; and usually it is the most deficient element in the soils that are said to be getting very "thin", especially in the worn hill lands and ridges, and also in very sandy hill soils. Ammonia (NH_3) is a compound containing one atom of nitrogen and three atoms of hydrogen, or 14 unit weights of nitrogen and 3 unit weights of hydrogen, or about 82 percent of nitrogen and 18 percent of hydrogen, as any one can determine for himself if he knows the atomic weights.*

Nitrogen is often sold under the name of ammonia, but one must buy 17 pounds of ammonia to get 14 pounds of nitrogen. Commercial nitrogen can be bought in the form of sodium nitrate,

*Hydrogen is the lightest element, and the weight of hydrogen is used as the measure of all elements. One atom of hydrogen weighs 1, while the atomic weight of nitrogen is 14, that of oxygen 16, phosphorus 31, sulfur 32, potassium 39, and calcium 40.

ammonia sulfate, or dried blood. The commercial value of nitrogen is at least 15 cents a pound; but the agricultural value of nitrogen when used on Illinois soils in general farming is never 15 cents a pound. In other words, while commercial nitrogen can often be used with profit in market gardening, all the records thus far secured show that the increase produced by commercial nitrogen in general farm crops on Illinois soils is never sufficient to pay the cost of the nitrogen applied, at commercial prices.

But why should we think of buying nitrogen? Nitrogen is absolutely the most abundant element of plant food, measured by crop requirements. The air over each acre of land contains sufficient nitrogen for a hundred-bushel crop of corn (grain and stalks) every year for more than 400,000 years, and sufficient carbon, in the form of carbon dioxid, for—How long? Four hundred thousand years? No. Forty thousand years? No. Four thousand years? No. Four hundred years? No. Forty years? No. Four years? No. The total supply of carbon in the air over one acre is sufficient for such crops for only two years. Of course, if only one-fourth of the earth's surface is land, if only one-fourth of the land is cropped, and if only one-fourth of 100 bushels of corn is the average crop, then the supply of carbon dioxid is sufficient for 128 years; and if carbon dioxid is constantly returned to the air in the breath of every animal and in every form of combustion, then the supply of carbon for plant growth is absolutely permanent.

In other words there is a natural carbon cycle, by which the carbon circulates, so that the supply in the air is perfectly maintained under all ordinary conditions. There is also a natural nitrogen cycle, by which the nitrogen circulates, so that under most natural conditions the supply of nitrogen in the soil is maintained, in large part by the native legume plants; but the average farmer destroys the nitrogen cycle, by his failure to grow and return to the soil a sufficient amount of leguminous crops.

But why should we think of buying nitrogen? Buy water, if you can in time of drouth; but don't buy nitrogen for general farm crops. Clover and all legume crops can get nitrogen from the air, while other crops cannot.

How then shall we add nitrogen to the soil? By plowing under clover or farm manure; keeping in mind that *for a 50-bushel crop of corn we must plow under 2 tons of clover hay or 8 tons of manure*; and keeping in mind that whoever fails to do as much as that will

finally have soil that will not produce 50 bushels of corn per acre; keeping in mind that the nitrogen of the soil is contained only in the humus or organic matter, which gives to the soil its black color; and that, if you are still producing fair crops of corn, oats, wheat, or timothy, without plowing under crops of clover or manure, you are still wearing out the humus of your soil, and that it will continue to get thinner and thinner so long as you continue thus to farm it.

Phosphorus is becoming deficient in most of the common prairie and upland timber soils of this state. Phosphorus is sold under the name of the actual element phosphorus, and also as phosphoric oxid (P_2O_5) which contains 62 parts of phosphorus and 80 of oxygen, or about 44 percent of phosphorus and 56 percent of oxygen. This compound is often incorrectly called "phosphoric acid." Phosphorus is also sold under a guarantee of "bone phosphate of lime" (B. P. L.), by which is meant tricalcium phosphate, $Ca_3(PO_4)_2$, a compound containing exactly 20 percent of phosphorus. In other words, when steamed bone meal or raw rock phosphate is guaranteed to contain 60 percent of "bone phosphate of lime," it is exactly the same guarantee as 12 percent of phosphorus.

Phosphorus can be bought delivered in most places in Illinois for 30 cents a pound in complete fertilizers, for 12 cents a pound in acid phosphate, for 10 cents a pound in steamed bone meal, and for 3 cents a pound in raw rock phosphate (fine-ground, in bulk, in carload lots).

Raw rock phosphate is not readily available, but it can be made available by the farmer, if he will plow it under with manure or clover; and, since he must plow under manure or clover in order to maintain the nitrogen of the soil, he may just as well use the cheapest form of phosphorus, which, it should be kept in mind, is the form of phosphorus originally contained in our natural soils, and which will never injure any soil.

If, instead of spending $4.60 an acre for the common commercial fertilizers to be used in such systems of land ruin as have been, and are still being, practiced to a large extent in the Eastern and Southern states, if, instead of this, the Illinois farmer will invest $4.60 an acre in raw rock phosphate every five years, his soil will grow richer in phosphorus the longer he farms it, unless he removes more than 100-bushel crops of corn, or unless the price of raw rock phosphate advances. (For further information about raw rock phosphate, see Circular 127, of the Illinois Experiment Station).

Potassium is contained in great abundance in all normal Illinois soils, but it is very deficient in most of the peaty swamp soils, and in some of the very sandy soils. Where needed it can be applied most economically in the form of potassium chlorid (incorrectly called "muriate" of potash). It is sometimes sold under the name of potash (K_2O) which contains two atoms of potassium (Kalium) and one of oxygen, or 78 unit weights of potassium and 16 of oxygen, or about 83 percent of potassium and 17 percent of oxygen. Commercial potassium chlorid contains about 42 percent of the element potassium.

On some soils that are very deficient in decaying organic matter, the potassium, tho present in immense quantity, may not be liberated with sufficient rapidity to meet the needs of large crops. On such soils (as the worn gray prairie land of Southern Illinois) the potassium must be liberated by supplying more decaying organic matter; or, temporarily, profitable use can be made of some soluble salts, such as Kainit. (For further information concerning the use of Kainit, and also concerning the need and use of lime, on Illinois soils, see Bulletin 123 and Circular 110.)

Can we permanently maintain the fertility of the soil by the use of commercial fertilizers?

At Rothamsted, where wheat was grown every year for 55 years with heavy applications annually of commercial plant food, the average yield for the 55 years is 37.1 bushels. For the first 30 years the average yield was 35.9 bushels, while 38.5 bushels is the average yield for the last 25 years, and 38.8 bushels is the average yield for the last five years in this 55-year period. Where no plant food has been applied the average yield of the last five years is 10 bushels.

At first thought, one might assume that these results would solve the problem of maintaining the fertility of the soil; and so they would, in large measure, except for one very practical difficulty. The total value of the average crop of 37.1 bushels of wheat at the average Illinois price for the last ten years, is $28.38, while the annual cost of the fertilizers applied is $28.33 per acre. In other words, it would take more than 37 bushels of wheat per acre to pay for the plant food applied. Furthermore where the supply of organic or humus is allowed to decrease the labor of tillage and the expense and difficulty of maintaining a good physical condition increases.

The best information upon this subject from American investigations is found in the records of the Pennsylvania experiments that have been in progress for twenty-seven years. If we dis-

regard the first three years which, as already explained, were required to get the rotation and soil treatments fully under way, we still have two 12-year periods for direct comparison.

These Pennsylvania experiments are conducted with a four-year rotation of corn, oats, wheat, and hay (mixed clover and timothy), and they cover four different series of plots, so that every crop is represented every year. In all, they include sixteen different experiments with commercial plant food, with nitrogen, phosphorus, and potassium, singly and in various combinations. Of these sixteen, there are only four which gave as large crop values during the second 12-year period as during the first 12-year period; and, of these four, not one gave sufficient increase in crop yields to pay for the cost of the fertilizers applied, when the values are determined by Illinois prices and allowance made for the other extra expense involved, such as the regular bills for binding twine, for threshing oats and wheat, for husking corn, and for baling hay.

From all the information the world affords, including careful experiments and common experience, the use of commercial fertilizers does not solve the problem of permanent agriculture for Illinois.

With the exception of a few small countries the record of our race is a record of ruined lands; and if we repeat, in the great corn belt of America, the history of the White Race in Palestine, in Southern Europe, in Russia, and in the Eastern part of the United States, where shall our children go for bread?

Gentlemen, if we are ever to adopt systems of permanent agriculture for Illinois it is high time we were about it; and not only on a few live stock and dairy farms, but likewise on the grain farms of Illinois.

It is truly a remarkable situation that, while some 75 percent of the farmers of Illinois and of most adjoining states are grain farmers, and while the percentage of grain farmers is increasing and live stock farming decreasing and becoming less profitable, still practically all the advice given to grain farmers concerning the problem of maintaining the fertility of the soil can be summed up in the words, "Become live stock farmers."

There are live stock journals by the score. Even single breeds, such as Jersey cattle and Berkshire hogs, have their own agricultural papers; poultry journals and bee keepers journals are published, whereas, there is practically no agricultural publication to furnish information as to how the grain farmer of the corn belt can keep up the fertility of his soil. The history of na-

tions shows that live stock decreases with increase in population. It also shows that live stock alone without the purchase of fertilizers or foodstuffs from outside sources does not keep up the fertility of the soil. There is no independent system by which the fertility of a farm can be kept up by merely returning to the land the manure that can be made by feeding only the crops produced upon that farm, and even if this were possible the system would not be applicable, because the world does not live upon animal products only. Bread is the staff of life, and grain must be produced and sold from the farms.

A writer in last week's issue of The Homestead (an agricultural journal which is now in its fifty-fourth year) makes the following statement:

> "While I am aware that it takes a lot of nerve to shovel out sixty-cent corn and tankage at $45 per ton to five and one-half cent hogs, yet what else can you do but keep a stiff upper lip and live in hopes that a better time is coming?"

The Breeder's Gazette is now publishing its fifty-fifth volume, and in last week's issue we read the following from an Illinois man:

> "I have been much interested in reading the letters of landlords, tenants, and farm laborers. I think there is often blame on all sides; that we have all been often short-sighted and selfish and impatient; that the landlord should consider the welfare of the tenant, and of the soil, and that the tenant should study to leave a farm better than he found it. I have been a farm laborer since I was 19. I am now 34.....In this time I have saved money enough to buy an 80-acre farm.....
>
> "I have now 50 acres in clover and the rest in blue grass. It has been pretty badly run down. I wish in a year to move on it and begin to build it up..... I plan to keep the place all in grass, to rent corn ground, feed the stuff on our own land, and thus build it up. Has Mr. Wing any suggestions for me?"

In his reply Mr. Joseph E. Wing says:

> "There could be no better plan for bringing up that rundown farm than to keep it in grass and clovers, feeding cows and colts and bringing part of the feed from some other man's place."

As men and citizens and brothers, what shall we say to this? Surely we will endorse this Illinois man's moral philosophy, "that the tenant should study to leave a farm better than he found it"; but can we also agree with him and Mr. Wing that when he comes to do business for himself he should forget this principle and deliberately plan to rent corn ground and feed the stuff on his own land?

Where is the jewel of consistency? How long can we main-

tain the fertility of Illinois soils if every man is to follow the plan of keeping up his own farm by hauling corn from his neighbor's land? The sum total of such practice is always loss to any community.

The question of maintaining the fertility of the soil of a state or a nation is larger than the interest of live stock farmers. Even a live stock farm whose fertility is maintained by means of manure made from the crops produced and from additional purchased foodstuffs is commonly only maintained for a single generation, while the next generation is unable to conduct the same sort of business with profit, and as a result this farm also then goes down in productive power.

There is absolutely no sense, in advising all of the grain farmers of the Great Central West to become live stock farmers. If they were to follow such advice the price of corn would double and the price of beef cattle and hogs would be cut in two. One of the most fundamental questions relating to the future welfare and prosperity of the people of the Central West is, How can the grain farmer continue a grain farmer and maintain the fertility of his soil? Let us not say this is impossible until we give it some honest consideration. In the first place, as already stated, it should be kept in mind that carloads of cattle and hogs are not made of nothing; also that 1000 bushels of grain has five times as great food value and will support five times as many people as the beef or pork that can be made from it; that as an average there are less than 800 pounds of dry matter in the manure produced by animals from 2000 pounds of dry food consumed. In other words, animals destroy about two-thirds of the total dry matter in the food consumed, and for the production of humus one ton of clover plowed under is worth as much as the manure that can be made from three tons of clover hauled off and fed. Less than half of the total plant food value of the food consumed is recovered in the solid excrement of animals, and as an average not more than three-fourths of the nitrogen and phosphorus can be recovered in the total excrements, solid and liquid.

In addition to this there is always a great risk and commonly much loss, from manure. A good live stock farmer, a graduate of the Illinois College of Agriculture, operating a large farm, finds that he is able to apply only ten tons to the acre of manure every seven years, whereas he will remove from the soil more plant food in two crops than the total amount applied in seven years. From the moment it is voided manure begins to ferment and decay, and loss of organic matter and of plant food also begins

by decomposition, volatilization, and leaching. It is of tremendous importance that great emphasis be laid upon the matter of prevention of loss and waste of manure; but even this is not the most fundamental question, because all of the manure that is made or can be made will not maintain the fertility of the soils; unless the United States can do as England does, consume all her own produce and import much more. Small commercial countries can do this, but great agricultural countries never can.

Absolutely the most fundamental question is, How can the grain farmer maintain the fertility of his soil? Is it possible? Yes it is; and not only possible, but it is simple and easy and profitable, and it can be done on the rented farms of Illinois as well as those operated by their owners.

First, let the landowner furnish more phosphorus for his farm than is removed in the crops; and, second, let him give sufficient thought to his farm to plan a good crop rotation and then let him see to it that the system he has planned is practiced. For example, one may adopt a four-year rotation such as the following, which may not be best for all conditions, but which is one of the best for the average conditions:

First year—Wheat, with clover seeding.

Second year—Corn, the young clover having been plowed under in the spring, as late as practicable, and after disking.

Third year—Oats, with clover seeding, the corn stalks having been disked down—not burned.

Fourth year—Clover, to be mowed once or twice in May or June and left lying on the land, only the clover seed crop to be harvested and removed that year.

When harvesting, leave as much of the straw in the stubble as practicable, and, when the wheat, oats, and clover crops are threshed, let the same wagons that haul the crops from the field to the machine haul back the straw and then throw it out in windrows across the field. Two or three extra teams may be required for this, but it is the best time and the most economical method of returning the straw to the land. Commonly all of the thrashed straw may be returned to one field, preferably perhaps to the field where oats have been harvested. After the thrashers have gone, the straw should be spread over the areas between the windrows, as uniformly as necessary to prevent smothering the young clover.

Some will say that this is too much work. If so, put the straw in the stack; afterward load it on to wagons and haul it to the barn; carry it in by armfuls and spread it uniformly over the

stalls; then, after it has soaked up as much liquid as it will hold, load it on to manure spreaders or wagons and haul it back to the field and spread it. Which method involves more work?

At some time during this four-year rotation 1000 pounds to the acre of fine-ground raw rock phosphate should be spread over the land to be plowed under with the decaying organic matter. This may be applied preferably on the clover ground to be plowed under for wheat.

In this system the only produce to be sold from the farm is the grain of wheat, corn, and oats, and the seed of clover. It is a system that will maintain the fertility of the grain farms, and the only requirement of the landowner, whether he lives on the farm or in the city, is to plan the rotation, furnish the phosphate, and see to it that the system is followed. If the common clover fails, (because of clover "sickness") we may substitute alsike clover, cowpeas, soybeans, or even sweet clover, for a time. This system, with possible modification to suit local conditions, will maintain the fertility of the soil, for it continuously provides sufficient amounts for good crop yields, both of nitrogen and phosphorus, and it also provides more organic matter and more humus than can be provided in any independent and practical live stock system of farming.

I do not advocate, especially, either live stock farming or grain farming. I do not advise the live stock farmer to become a grain farmer; neither do I advise the grain farmer to become a live stock farmer; but I do advise both live stock farmers and grain farmers to adopt and practice systems of farming that will maintain the fertility of their soils.

In conclusion let me repeat what I said to the Illinois State Farmers' Institute six years ago:

The only system of maintaining soil fertility which I can advocate, and which can ever be safely adopted as a permanent system, must be a system which can be applied to all of the soils of this State—not to a few farms only, or for a few years only, but to all the soils of Illinois and for all time.

The fertility of Illinois ought not and need not be reduced; Illinois land ought never to be reduced below its original productive capacity.

If he who makes two blades of grass grow where but one grew before is a public benefactor, then he who reduces the fertility of the soil so that but one ear of corn grows where two have been grown before is a public curse.

TURNIP CROP OF 1908 ON AGDELL FIELD, ROTHAMSTED; 61st CROP IN 4-YEAR ROTATION

1 2	3 4	5 6
Unfertilized	Mineral plant food	Minerals and nitrogen

Counting from the left, lots 1, 3, and 5 were grown on land where the rotation is turnips, barley, clover, and wheat, while lots 2, 4, and 6 were grown on land where the rotation is turnips, barley, fallow, and wheat.

The six lots were all produced on plots of ground of equal size. Plots 1 and 2 have received no fertilizer.

Plots 3 and 4 received only a phosphorus fertilizer for the 36 years, 1848 to 1883, but since that time they have received mixed minerals, including phosphorus, potassium, magnesium, and sodium. (The average yield of turnips in 1880 was 1½ tons for plots 1 and 2, and the average yield of plots 3 and 4 for the same year was 12¼ tons, per acre.) Plots 5 and 6 have received mixed minerals and nitrogen since 1848.